

Soils as Sponges: How Much Water Does Soil Hold?



Purpose

To introduce students to “gravimetric measurements” – calculating the amount of water in a soil sample or other substance by weighing it before and after drying

Overview

Students weigh a wet sponge, squeeze it to remove water and then weigh the dry sponge.

Student Outcomes

Students will understand that objects can hold a measurable amount of water.

Students will be able to transfer this concept to soil, weighing wet and dry soil samples, and then apply this wet/dry comparison to other objects, such as leaves and fruit.

Science Concepts

Earth and Space Science

Soil consists of weathered rocks and decomposed organic material.

Water circulates through soils affecting its properties.

Scientific Inquiry Abilities

Identify answerable questions.

Use appropriate mathematics to analyze data.

Develop descriptions and explanations using evidence.

Communicate procedures and explanations.

Time

Approximately two class periods for the initial sponge and soil activities; then 10-15 minutes per day for about 3 days, as objects dry

Level

Middle and Secondary

Materials and Tools

Scale or balance

Several sponges

Paper towels

Graph paper (for intermediate or advanced)

Soil samples

Other objects to dry (such as fruit, leaves, vegetables)

Prerequisites

Knowledge of fractions and decimals

Background

Many objects hold water. For living beings, this water is essential for survival. In the case of soil, this water is essential for the survival of the plants and animals that live or grow in the soil. Scientists use soil moisture data to predict what will grow in an area.

One way to calculate soil moisture is to take a gravimetric measurement of a soil sample. Gravimetric means to find the weight, or the pull of gravity, upon an object. When calculating soil water content, we want to find the weight of the

water contained in the soil. To do this we measure the weight of a soil sample, dry it out, and then measure the weight of the dried soil. The difference in the weights is the amount of water originally in the sample. We then normalize by dividing by the dry sample weight.

For example, you might dig up a handful of soil and find that it weighs 100 grams. After the soil has dried, you weigh it again and find that it only weighs 90 grams. Ten grams of water have evaporated from the soil, but this must be normalized, to remove sample size bias, by the



weight of the dry soil ($90 - 30 = 60$ g assuming a 30 g can weight). We can calculate the fraction $10/60=0.167$. This is a measure of how much water is in the soil (water content). Since we are using a balance, which depends upon gravity, this is called the gravimetric water content.



Soil water content calculations are simple to do, as long as samples are measured accurately. When the air is dry, evaporation can happen quite rapidly. Think about how fast you dry off after getting out of the pool on a hot, dry day. Soil samples will dry quickly in the air as well, if they are not placed in a sealed container as soon as they are removed from the ground.



Soil moisture is influenced by many environmental factors, such as temperature, precipitation and soil type, as well as topographic features, such as slope and elevation. Soil moisture is especially important for agriculture. Much of the hard work of farming, such as plowing and discing, is done to try to improve the soil-moisture related properties of the soil. Terracing (making ridges in a field) is done in some areas to prevent too much runoff, while fields are rounded in other places to keep the soil from staying too wet. Further, different crops require different amounts of water throughout their growing season. Understanding how the soil moisture changes through the year can help a farmer decide what to plant.



In this activity, students measure the moisture in several objects. They do these experiments in five stages of increasing difficulty:



Stage 1 – Squeezing water from sponges

Students weigh a wet sponge, squeeze it, then weigh the dry sponge and the water that was squeezed from the sponge. Doing this, they see that a wet sponge = dry sponge + water. Squeezing is a very visible and immediate way to release water.



Stage 2 – Evaporating water from sponges

Students do the same exercise as above, except that they let the sponge sit for several hours or a day to let the water evaporate. When they weigh the dry sponge, they should get approximately the same weight as in stage 1 (although evaporation may have removed more water than the squeezing did).

Stage 3 – Measuring soil moisture

Now students transfer the concept of evaporative drying to soil by letting soil samples dry for a day or two. They measure the weight before and after to measure the soil moisture. They compare several soil samples to get a sense of a typical range of values.

Stage 4 – Removing water from other objects

Students transfer the concept of soil moisture to determine the moisture of other objects, such as fruit or leaves. They experiment with different ways to dry the objects: fans, squeezing, sunlight, salt, etc. They also estimate the wetness values.

Stage 5 – Using GLOBE visualizations for worldwide soil moisture

Students use the GLOBE visualizations on the Worldwide Web to study a map showing soil moisture in other parts of the world. They discuss why there are differences, and conduct further investigations based on student interest in the topic and the visualizations.

What To Do and How To Do It

Preliminary Exercise

If your students do not know how to use the scale or balance, you should teach them how and let them practice weighing objects.

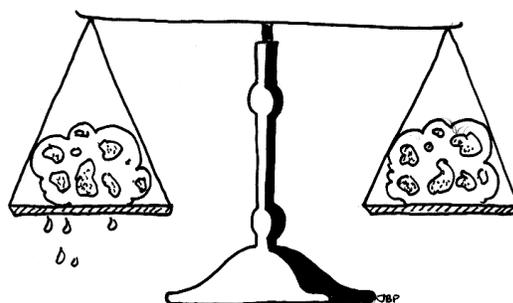
Stage 1 – Squeezing water from sponges

1. Soak a sponge in water. Weigh it and record the wet weight. Ask your students how much they think it will weigh when it is dry. Record the estimates.
2. Squeeze the sponge and weigh it. Record the dry weight. Discuss with students how their estimates compared with the actual value.
3. Ask your students how much water was in the sponge. See if they can figure out how to calculate this. This amount of water = wet weight of sponge minus the dry weight of sponge. For example, 120 grams of water = 200 gram wet weight minus 80 grams dry weight.
4. Now repeat the measurements with a different sponge. Have your students figure out which sponge can hold the most water.
5. You now have an absolute measure of the water content. Next find the relative measure of water by dividing by the dry sponge weight.
6. To extend this activity, for each sponge you can collect the squeezed out water in a plastic cup, and then weigh the water (make sure you deduct the weight of the cup to get the weight of the water itself). The actual weight of the water should be the same as the calculated weight.
7. In your discussion with your students, make sure they understand the concept of water-holding capacity, and that this differs from one type of sponge to another.

Stage 2 – Evaporating water from sponges

1. Ask your students what will happen if you leave the wet sponge on a tray overnight instead of squeezing it. If your students understand the concept of evaporation, you can discuss that with them. Otherwise, wait until later in this activity to discuss evaporation.

2. Have your students weigh the wet sponge, record the weight, and leave the sponge on a tray, preferably in sunlight. Leave it exposed until the next day.
3. After the sponge has been left out for a day, have your students weigh the dry sponge (it should be dry by now).
4. Ask your students where the water went. Older students who understand evaporation will know the answer. Otherwise explain evaporation to your students.
5. Calculate how much water left the sponge to find out its water-holding capacity. This figure may be different from what they measured when they squeezed the sponge. Ask them why the numbers are close (because both squeezing and evaporating removed most of the water), and then ask them why the numbers are not exactly the same (because evaporation removes more than squeezing, although it takes longer).
6. Ask your students why a high water-holding capacity is important for a sponge, and what other objects might need a high water-holding capacity.



Homework

Explain to your students that they will soon be measuring how much water soil can hold. Ask them to bring in a soil sample from home. They should put the soil sample into a small plastic sandwich bag, then seal the bag to retain its moisture.



Stage 3 — Measuring the moisture of soil

1. Have your students put their soil samples (still in the tightly-sealed plastic bags) on their desks or tables. Ask them how they might measure the wetness of the soil. In their answers, the central concept to look for is to weigh the wet soil, dry it (there are many ways to dry it), and weigh it again, just as they did with the sponge.
2. Have each student or group of students open their sealed baggy, weigh the wet soil, and set it aside to dry. Drying may take a day or two.
3. When the soil is dry (have them touch the soil to feel how dry it is), have your students weigh each soil sample again. Ask them how much water evaporated.
4. Introduce the formula for soil water content. Soil water content =

$$\left(\frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Dry Weight} - \text{Can Weight}} \right)$$

This is the formula used in the soil moisture protocol. For example, if the wet weight is 100 grams and the dry weight is 90 grams, and the can weight is 30 grams then the soil water content will be

$$\frac{100 \text{ g} - 90 \text{ g}}{90 \text{ g} - 30 \text{ g}} = \frac{10}{60} = .167$$

5. Have your students calculate the water content of their soil and compare the values. Correct any errors in their calculations. Discuss the range of values and why they think there is such variety. Have them examine the different soils to help them think about why there is such a range.

Intermediate and Advanced Students

In the previous activities, older students can weigh the soil every hour, and then graph the results to see whether water evaporates at a constant rate or the evaporation rate changes, such as slowing the closer the soil gets to being dry, or evaporating more quickly when the sun is shining on it. You might also link the discussion with weather factors, such as how quickly the soil might dry on very dry or humid days.

Homework

Explain to your students that they will be drying other objects. Ask them to bring to class some fruits, vegetables, leaves, rocks or anything else they are interested in experimenting with.

Stage 4 — Removing Water From Other Objects

1. Have your students show and discuss the objects that they brought in to dry. Have them estimate the water content for each object. Record their estimates, either as individual estimates or as class estimates.
2. Have your students weigh each object and record its wet weight.
3. Brainstorm with your students for ways to dry the objects. Previously they squeezed and evaporated water. What other ways are there? How could they speed up or slow down the process? Some ideas are: put the objects in direct sunlight; blow a fan over them; put them on a heater; put them in a microwave or oven; pour salt on them; cover them with a plastic container; point a light on them.
4. Select among the techniques and see the results. The more time you have available, the more your students can experiment.
5. After one or a few days, when the objects are dry, have your students weigh them again. Then have them calculate the wetness of each object. Compare the actual values with their estimates. Which results surprised them?



Stage 5 — Using GLOBE Visualizations for worldwide soil moisture

Intermediate and Advanced Students

This activity is appropriate for intermediate and advanced students who have the requisite map-reading skills and basic understanding of soil moisture issues. Do this activity after your students have begun submitting soil moisture data based on the GLOBE soil protocols.

1. Use the GLOBE Web page to access and display a map showing soil water content around the world based on the most recent student measurements. This is an exciting opportunity for your students because soil moisture data from all over the world have never before been available.
2. You can display the soil water content data either as values or as contours (with different colored bands corresponding to certain ranges of soil moisture values).
3. Make sure your students make the connection between their own soil water content measurements and the soil water content readings from other schools around the world.
4. There are many domains of investigation for your students. Here are some examples:
 - what is the range of soil water content values around the world?
 - where is it the lowest? the highest?
 - does this vary over time? (examine soil water content maps from other months)
 - what affects the soil water content of the different sites?
 - do soil water content values depend on recent weather conditions?
 - compare readings from a desert, a rain forest and a farming area
 - what areas have about the same level of soil water content as your site?
5. Encourage your students to pursue further investigations using the GLOBE soil water content visualizations.

Student Assessment

Bring a set of soil samples to school. Have your students estimate the soil water content. Have them calculate the soil water content (do not remind them how). Check for reasonableness in their estimates, and watch the process to make sure they do it correctly.